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TESTS OF SWEET CORN LINES FOR RESISTANCE TO EUROPEAN CORN BORER LARVAE[1]

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INTRODUCTION

Progress made in the investigation of the resistance of dent corn to the European corn borer (*Pyrausta nubilalis* (Hbn.)), as reported by Ficht (*2*),[3] Meyers *et al.* (*4*), and Patch *et al.* (*6*), led to similar research on the resistance of sweet corn (*Zea mays* L.) to the insect. The studies with sweet corn reported by the present authors were conducted at Toledo, Ohio, from 1935 to 1941, inclusive, and at Lafayette, Ind., in 1942,[4] with materials furnished by Federal and State agencies. The purpose of this paper is to present and discuss those inbred lines of Bantam, Country Gentleman, and Evergreen sweet corn that were most promising from the standpoint of their inherent resistance to the survival of European corn borer larvae. The data given for inbred lines and their crosses should not be construed as evaluating their usefulness to the grower. The investigation was limited to finding inbred lines of sweet corn with inherent resistance which could be utilized by the corn breeder.

In discussing the use of resistant plant hosts to minimize the effects of insect attack, Snelling (*10*) pointed out that, although the general concept of resistance imposes the realization of normal or nearly normal development of an acceptable host in the presence of an inimical agent, such development is a consequence of the inherent capability of the host totally or partially to escape invasion by, inhibit the de-

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[3] Italic numbers in parentheses refer to Literature Cited, p. 156.

[4] The work in 1942 was conducted cooperatively with the Bureau of Plant Industry, Soils, and Agricultural Engineering, of the U. S. Department of Agriculture, and the Departments of Entomology and of Botany and Plant Pathology, of the Purdue University Agricultural Experiment Station.

velopment of, or tolerate the attacking agent. It is evident, therefore, that the causal expression of the resistance can be manifested both in the effects of the host on the attacking agent and in the effects of the attacking agent on the host. In the interrelationship of the corn plant and the corn borer it was recognized at the outset that differential rates of oviposition and also of larval survival afforded criteria of resistance as to the effect of the corn plant on the corn borer. Similarly, it was recognized that differential rates of plant breakage, yield reduction, and ear damage provided criteria of resistance associated with the effect of the corn borer on the plant.

The relationships of larval populations in the plants to the losses in sweet-corn production and use focused the immediate attention of the investigators on the resistance of the corn plant to the survival of the larvae. Owing to the concentration of borers on early planted sweet corn, severe infestations by European corn borer larvae and occasionally a total crop loss have been common, even in areas of generally light attack. Usually the sharp reductions from potential yield and the severe damage to the ears are in direct relation to the numbers of larvae present in the plants. However, some cornfields attacked late showed practically no reduction in potential yield, although a severe crop loss resulted from direct feeding of the larvae on the ears. Where the crop is only partially reduced, borer damage and the presence of the larvae lessen the market value of the ears. In corn grown for canning, the labor and cost of processing and the danger of contamination of the canned product are increased in proportion to the number of larvae present.

SWEET-CORN LINES TESTED

Breeding for borer-resistant sweet-corn lines was undertaken by Marston and Mahoney (*3*). They crossed commercial types of sweet corn with Maize Amargo, a South American flint corn reported by them to be resistant to the corn borer, and tested the sweet-corn recoveries from these crosses under conditions of natural infestation. They used the percentage of plants that showed evidence of borer infestation as the criterion of resistance and presented evidence of the inheritance of resistance in the sweet-corn recoveries.

The present writers considered it necessary first to survey the resistance possibilities of the available released and experimental sweet-corn lines developed by Federal and State agencies. The study of inbred lines as such was stressed to provide sources of resistance for use in future programs leading to the development of new lines of greater resistance by breeding, and the improvement of commercial lines by transfer of the resistance factors to them. Some of the lines tested were recoveries from sweet corn crossed with dent corn of known corn borer resistance; for example, the inbred lines developed by Marston and Mahoney (*3*). A number of the inbred sweet-corn lines found to be relatively resistant to the corn borer were of proved agronomic value, but others represented experimental lines of little worth except for the resistance factors they carried. In general, the tests of crosses among the inbred lines were made only to determine the general transmission of the resistance shown by their inbred components.

From 1935 to 1939, inclusive, all the lines and crosses entered in the tests were furnished directly by the corn breeders. Serious difficulty was encountered, however, in obtaining additional seed of some lines for continued testing, as the lines had been discarded by the breeder as being agronomically undesirable before their possible value as a source of borer resistance was determined. To avoid the loss of desirable resistance material, a number of plants of each entry in the tests were selfed by hand each year, beginning in 1939, for seed production. Seed was also produced to obtain necessary crosses among the inbred lines. Although much of that seed was later discarded, the practice ensured the continuity of tests and of lines where necessary.

A total of 977 inbred lines and strains within the lines, representing Bantam, Country Gentleman, and Evergreen types, were given 1,567 tests during the years 1935–42. The numbers of lines of each type and the sources from which they were obtained are given in table 1. A total of 708 tests of single crosses among the inbred lines were also made during the same period, and the numbers of tests of inbreds and crosses of the different types made each year are shown in table 2.

TABLE 1.—*Numbers and sources of various inbred lines of sweet corn tested for resistance to survival of European corn borer larvae, 1935–42*

Source	Bantam	Country Gentleman	Evergreen	Total
Connecticut	10		5	15
Illinois	34	86	46	166
Iowa	59	25	24	108
Maryland			20	20
Michigan	127			127
Minnesota	33			33
New York	8			8
Ohio	6		14	20
Indiana [1]	312	91	55	458
Wisconsin	16	5	1	22
Total	605	207	165	977

[1] U. S. Bureau of Plant Industry, Soils, and Agricultural Engineering, in cooperation with Purdue University Agricultural Experiment Station.

TABLE 2.—*Numbers of sweet corn inbreds and hybrids tested for resistance to European corn borer larvae, 1935–42*

Year [1]	Bantam		Country Gentleman		Evergreen		Total	
	Inbreds	Hybrids	Inbreds	Hybrids	Inbreds	Hybrids	Inbreds	Hybrids
Toledo, Ohio:								
1935	17	20	12	25	13	11	42	56
1936	39	22	28	16	41	15	108	53
1937	29	45	72	42	31	33	132	120
1938	315		45		38		398	
1939	178		63		63		304	
1940	148	78	67	67	55	55	270	200
1941	118	184	51	44	51	36	220	264
Lafayette, Ind.:								
1942	49	10	23	3	21	2	93	15
Total	893	359	361	197	313	152	1,567	708

[1] The numbers of entries in any year comprise tests of new material and retests of material used previously.

During the 3-year period 1935–37 the tests were mainly restricted to released inbred lines and hybrids and to experimental inbreds and hybrids of possible commercial value, to determine their relative reaction in respect to the survival of corn borer larvae. In 1938 and 1939 all the available facilities were concentrated on the testing of inbred lines as such, regardless of their agronomic significance, to determine sources of resistance factors. In 1940–42 the inbred material tested consisted mainly of series of ear lines of the more promising resistant inbreds found, and also of a number of the more widely used commercial lines, to determine the possibility of selecting more resistant lines from them. Most of the crosses tested in those years comprised single crosses of resistant and susceptible inbreds.

EXPERIMENTAL PROCEDURE

Each year the sweet corn entries were tested under natural infestation and also under supplementary uniform infestation of the plants with corn borer egg masses by hand. The plants were hand-infested to ensure an adequate test of all lines, independent of chance natural infestation. The egg masses for the hand-infestation treatment were produced in the laboratory by a modification of methods described by Patch and Peirce (7) and when nearly ready to hatch were placed on the plants. The individual egg masses on waxed paper discs were pinned on the upper side of the midrib of the middle leaves of the main stalk of the corn plant, close to the juncture of the leaf and the sheath. The infestation rate per plant ranged from 2 to 4 egg masses of about 30 eggs each.

The inbreds and hybrids were tested separately with further separation in different experiments of the Bantam from the Country Gentleman and Evergreen types, to avoid competitive effects. Randomized blocks with single-row plots were used. The blocks were replicated from 3 to 6 times and were 80 inches apart. The plot rows were 40 inches apart and the plants were approximately 15 inches apart in the rows. Each plot row was equally subdivided to accommodate natural infestation alone in one part and supplementary hand infestation in the other. The infestation treatments were separated either by buffer plants or by 40 inches of space. Buffer plants were also provided at the ends of the plots and in buffer plots at the ends of the blocks. Adjacent experiments were 120 inches apart. Data were taken on 5 or 10 plants of each infestation treatment, the total number per entry of 15 to 30, varying with the number of replications.

Plantings of the test entries were made during the latter third of May, since the corn planted during this period usually received a minimum of infestation from both spring and summer broods of the borer. All the entries of a specific experiment were planted on one date. The plants were hand-infested in July, and all the entries of a specific experiment were infested on one date. An effort was made to infest the plants by hand when the silks were beginning to appear on some of the test entries. By that time all the entries were sufficiently advanced in stage of plant development to ensure adequate rates of survival of the larvae for evaluation purposes and none was too far advanced for a satisfactory test. Generally, the peak of hatching of the eggs from natural infestation (single and first genera-

tion) was about a week earlier than that of the eggs placed on the plants by hand. The corn plants were dissected for borer counts approximately 25 to 30 days after the hand infestation, when nearly all the larvae were full grown and possible losses by migration were inconsequential. The larvae that hatched from the second-generation eggs were readily distinguished by their small size and were eliminated from the borer counts. Whenever possible, the plant dissections in an experiment were completed on one date.

EVALUATION OF RESISTANCE

FACTORS AFFECTING BORER POPULATIONS

Although all the entries in an experiment were uniformly infested with borer eggs by hand on one date, in the evaluation of resistance the counts of borers surviving in the different entries were not directly comparable, because of the varying effects of the different growth habits of the respective entries on the rates of natural infestation and on borer survival. The taller plants received larger numbers of eggs laid naturally, and those in advanced stages of plant growth were more favorable to survival of larvae. Neiswander and Huber (*5*) showed these relationships for dent corn and Beard (*1*) for sweet corn. The numbers of tillers, the relative vigor of the plants, and the presence of tassels in plants infested in a similar manner were found to contribute to fluctuations in the number of borers.[5] As these factors varied for the same lines in relation to competition and environment, they had to be considered in the category of experimental variation in determining the inherent resistance or susceptibility of the different lines to borer survival. Since no satisfactory method could be found of preventing these experimental variations and their attendant influence on the borer counts, it was necessary to measure them and take their associated effects into account by statistical analyses, using the multiple covariance method described by Snedecor (*9*). These analyses led to the appraisal of the borer resistance of the respective entries, as if all had been uniformly tested with respect to the factors considered. The factors measured and their use are briefly discussed.

The rates of natural infestation, in terms of resultant larval populations, were obtained from the plot sections that received this type of infestation only. These data were used to account for the effects of differential rates of natural egg infestation in the hand-infested plot sections, the borer counts from which reflected both natural and hand infestation. The number of days that elapsed from the date of hand infestation of the plants to the date of tassel or of silk emergence on 50 percent of them afforded a measure of the relative growth stage of the line when infested. This period was used to account for the influence of stage of plant growth on borer survival. The effects of factors (both nutritive and protective) associated with the presence of the tassel, and conducive to higher borer survival, were accounted for by use of the percentages of plants that showed tassels when the eggs were placed on the plants. At the time of infestation the height of each plant was measured from the ground surface to the tip of the

[5] Unpublished data of the present authors.

leaf when the plant was brushed upward through the hand. This measurement was used in accounting for possible differential effects of plant vigor on survival of larvae. The effects of differential numbers of tillers on borer survival were determined from the numbers of tillers per plant when the plants were dissected for borer counts. Measurements of all the known factors that might have influenced the borer counts in the hand-infested plots were made in each experiment each year, but in specific experiments and years only those factors that a preliminary study of the data had revealed to be of consequence were considered. Generally the more important effects were found to be associated with differential natural infestation and stages of plant growth.

DETERMINATION OF RESISTANCE

The mutual relationships among the variable factors considered in an experiment, and their effects on the borer populations in the lines, were determined by analyzing their covariance. A multiple regression equation was then computed for predicting the number of borers per plant to be expected under the particular test conditions of each entry. The predicted borer populations were obtained by successively substituting in the equation the mean results of the measurements of the factors for the specific entries. With a few exceptions, the equation regression coefficients were calculated from the random-error statistics, thus freeing them from the effects of line and replication influence, as pointed out by Snedecor (*9*). The deviations of the observed from the predicted numbers of borers per plant reflected, therefore, the influence on borer survival of all factors the effects of which were not taken into account, thus providing a basis for distinguishing the possibly resistant or susceptible lines. Entries that showed materially more or less than the predicted number of borers per plant were tested further. The entries that were highly consistent through a succession of tests were classed as relatively resistant or susceptible to borer survival, depending on whether they showed an average of less or more than the predicted borer populations. For comparison, the deviations of the observed numbers of borers per plant from the predicted numbers were calculated as percentages, thus converting the proportional relationship between the deviations and the predicted borer populations into a uniform scale of measurement.

The numbers of borers per plant were used in analyzing the data during the years 1935-39 and the logarithms of those numbers were used during the years 1940–42. The change to the use of the logarithms was made because, according to Snedecor (*9*), this was the proper procedure in tests where the group means and the standard deviations tended to be proportional. However, owing to the general conformity of the results where either method was used, it was not necessary to recalculate the data for the years 1935–39.

In the procedure followed, as outlined above, the test entries were evaluated for their response to the corn borer when infested at a given stage of plant development in any specific experiment or year. The question arose, therefore, whether the resistance or susceptibility thus determined would indicate the reactions of the lines when the infestation occurred at other stages in their growth. In 1939 the present authors (*8*, *fig. 1*) showed that approximately four times as

many larvae, on an average, became established in the susceptible inbred Conn. 2 as in the resistant inbred Mich. 1828, when both were similarly infested with corn borer eggs by hand at any stage of growth up to the approximate time when 50 percent of the plants had silked. The uniformity of the ratio between the resistance shown by Mich. 1828 and that shown by Conn. 2 throughout the entire range of growth that might become infested appeared to warrant continuation of the procedure described.

DISCUSSION OF RESULTS

None of the 977 inbreds examined showed immunity to the establishment of European corn borer larvae, but among them 44 did manifest some degree of resistance to the survival of larvae on the basis of numbers less than were predicted for them from tests running through 3 or more years. The source, the total number of tests, and the mean results by years for each resistant line, as compared with susceptible lines, are given for the Bantam, Country Gentleman, and Evergreen types, respectively, in tables 3, 5, and 8. The percentage deviations from predicted numbers of borers shown for the respective lines in particular years represent either the performance of a single entry or the mean of the results obtained for multiple entries of the line in that year, usually a series of ear lines of the strain. A decrease from the predicted number of borers, connoting resistance, is indicated by a minus sign, and an increase, connoting susceptibility, by a plus sign. The data in the last column of each table are the averages for the yearly results shown. These percentage-deviation averages are the best estimates of the inherent degrees of resistance or susceptibility of the different lines with respect to borer survival.

In view of the expression of resistance as the percentage deviation of the observed from the predicted number of borers, a question may arise as to the meaning of the results in terms of borer populations in the lines. Obviously, while the borer populations may be expected to vary for particular lines in different experiments, the percentage deviations of the observed from the predicted borer populations should remain the same within the limits of random variation. Consequently, whereas the percentage deviations represent characteristic constants for the lines within the limits of random error, the borer population rates are only descriptive of the behavior of the lines under certain conditions of test. For example, under different conditions potentially productive of 5 and 10 borers per plant (table 3), inbred Pur. W675–1 would be expected to contain 2.9 and 5.8 borers per plant, or 0.58 times as many borers as the potential or predicted number of borers in each case, this being 42 percent less, or the characteristic degree of resistance for the line. Similarly, under the same respective conditions of test inbred Pur. 39 would be expected to contain 5.3 and 10.6 borers per plant, or 1.06 times as many borers as the potential number in each case, this being 6 percent more, or the characteristic degree of susceptibility for this line. Comparing the two lines, Pur. 39 would be expected to contain 1.8 times as many borers as Pur. W675–1 under each condition of test, 5.3÷2.9 and 10.6÷5.8.

On the basis of the percentage-deviation averages shown in tables 3, 5, and 8, the results for all the different lines of sweet corn ranged

TABLE 3.—*Relative resistance of inbred lines of Bantam sweet corn to European corn borer larvae, Toledo, Ohio, 1935–41, and Lafayette, Ind., 1942*

Inbred line [1]	Total number of tests	Number of tests showing fewer borers than predicted	Percent deviation of observed from predicted borer population [2]								
			1935	1936	1937	1938	1939	1940	1941	1942	Mean
Pur. W675-1	6	6	.....	.....	.....	−30	−44	−17	−72	−49	−42
Ia. 461	4	4	.....	.....	.....	.....	−27	−68	−13	−33	−35
Mich. 3116	10	10	.....	.....	.....	−52	−11	−26	−42	−34	−33
Mich. 1828	77	61	.....	−38	−80	−45	−14	−35	−9	−9	−33
Ia. S5010-9	6	6	.....	.....	.....	−52	−22	−27	−18	−40	−32
Minn. 13-34	3	3	.....	−20	−46	−15	.....	.....	.....	.....	−27
Ia. 9	22	17	.....	−55	−46	.....	−33	−28	−14	+19	−26
Minn. 77	4	4	.....	.....	.....	.....	−14	−48	−24	−15	−25
Minn. 26-34	21	16	.....	−42	−64	−14	−20	−28	+12	−19	−25
Wis. 515	3	3	.....	.....	.....	.....	−34	−9	.....	−22	−22
Ia. 45	6	6	−20	−33	−30	−37	−11	−10	+5	+18	−15
Pur. 14	16	8	−8	−9	.....	−41	−13	+10	+13	+56	+1
Pur. 51	24	8	+6	+18	−29	−18	−11	+54	−4	+11	+3
Pur. 39	46	16	−24	−1	+9	−13	+24	+8	+36	+11	+6

[1] Where inbred line was developed.
[2] Where more than a single test was involved in a specific year the mean result is given.

from 42 percent less to 33 percent more than the predicted or potential number of borers for the conditions of test. Of the inbreds in the resistant category, exclusive of those showing apparent differential behavior in successive periods of testing, as will be discussed later, 11 showed decreases from potential infestation ranging from 2 to 9 percent, 8 showed decreases ranging from 13 to 17 percent, 10 showed decreases ranging from 22 to 28 percent, 7 showed decreases ranging from 32 to 37 percent, and 3 showed decreases of 42 percent. Although relatively low in inherent resistance, the material constitutes a source of possibly differing factors for breeding lines of greater resistance. Patch *et al.* (*6*) have indicated that multiple factors are involved in the expression of borer-survival resistance in field corn and that the degree of resistance shown is proportional to the number of differing resistance factors present.

Several inbred lines among the different types of sweet corn tested in 1935–39 consistently reversed their performance with respect to the survival of corn borer larvae when tested during the years 1940–42. The inbred lines that shifted from apparent resistance during the earlier period to apparent susceptibility in the later were Pur. 14 (table 3), Pur. S10 and FR22 (table 5), and Pur. 119 (table 8). On the other hand, an apparent change from susceptibility in the early period to resistance in the later was noted for the inbred Pur. 1099 (table 8). No definite reason is known for the differential behavior of these inbred lines during the two periods of testing. A possible explanation, which, however, should be viewed with caution in the absence of critical research, may lie in the source of the larvae involved in each period. In the tests conducted during the period 1935–39, larvae of the univoltine, or single-generation, strain of the borer predominated, whereas during the period 1940–42 larvae of the bivoltine, or multiple-generation, line were more abundant.

Some information on the general prepotency of the resistant and susceptible inbreds was obtained from their performance in single-

cross combinations. Pertinent data are given in table 4 for the Bantam inbreds, in tables 6 and 7 for the Country Gentleman inbreds, in tables 9 and 10 for the Evergreen inbreds, and also in the detailed discussions of the inbreds that follow. The data at hand indicate incomplete dominance of either resistance or susceptibility in the combinations of resistant and susceptible parents, since the results of most of these combinations were intermediate between those obtained from combinations of resistant parents and those obtained from combinations of susceptible parents. This is particularly evident from the data of table 4, involving the results obtained from all possible single-cross combinations among the resistant inbreds Ia. 461, Mich. 1828, Ia. 9, and Minn. 26–34 and the susceptible inbreds

TABLE 4.—*Percentage deviation of observed from predicted population of European corn borer larvae in single crosses among the relatively resistant and the relatively susceptible Bantam sweet corn inbreds, Toledo, Ohio, 1940–41*

Inbred line	Inbreds used in crosses						
	Ia. 461	Mich. 1828	Ia. 9	Minn. 26–34	Pur. 14	Pur. 51	Pur. 39
Resistant:							
Ia. 461	------	−12	−30	−25	0	−19	−10
Mich. 1828	−12	------	−28	−24	−12	−9	−6
Ia. 9	−30	−28	------	+29	−16	+10	+8
Minn. 26–34	−25	−24	+29	------	−12	−14	+28
Susceptible:							
Pur. 14	0	−12	−16	−12	------	+26	+19
Pur. 51	−19	−9	+10	−14	+26	------	+25
Pur. 39	−10	−6	+8	+28	+19	+25	------
Mean	−16	−15	−5	−3	+1	+3	+11

Pur. 14, Pur. 51 and Pur. 39. The crosses between the resistant and susceptible inbreds averaged 6 percent less than the predicted number of borers, as compared with 15 percent less and 24 percent more, respectively, for the crosses within the resistant and susceptible groups. Owing to the limited amount of research conducted with the single crosses, the results shown for them, although possibly indicative, are inconclusive for appraising the specific prepotency of their inbred components.

As previously explained, many of the inbred lines showing some degree of resistance represent experimental materials of possibly little agronomic value. A number of the inbred lines that were found resistant, however, were in commercial use because they possessed desirable agronomic characteristics. These are Minn. 77, Ia. 45, Pur. 14, Ia. 1627, Ia. 1445, Ill. 8, Pur. FR22, Md. H84, Ill. 55, Ill. 13, and Ill. 11. It was outside the scope of this investigation to appraise either the experimental or the commercial lines for performance from the standpoint of the grower. The data given for the inbreds and their crosses measure their relative resistance or susceptibility with respect to borer survival under similar conditions of test, whereas under field conditions their relative performance, as appraised by the numbers of borers they contain, would be expected to reflect the effects of varying influences in addition to resistance or susceptibility. Obviously, this latter consideration, although important to the grower,

bears little relation to the availability of the inbred lines themselves as reservoirs of resistance for use by the breeder. It is recognized, however, that to be of economic value any new line of corn bred from the resistant stocks must bring together sufficient resistance to more than offset modifying influences in the field and must also possess satisfactory agronomic characteristics.

The inbred lines shown in tables 3, 5, and 8, are discussed individually for the Bantam types and generally for the Country Gentleman and Evergreen types, owing to the character of the information at hand.

BORER RESISTANCE OF BANTAM INBRED LINES

On the basis of larval populations less than predicted for them under the conditions of test, the following Bantam inbreds were classed as borer-resistant: Ia. 9, 45, and 461, and S5010–9; Mich. 1828 and 3116; Minn. 77, 13–34, and 26–34; Pur. W675–1; and Wis. 515. The results obtained for these lines are given in table 3, along with the results obtained for the inbred lines Pur. 14, Pur. 39, and Pur. 51 for comparison.

Owing to their wide use in the production of commercial hybrids, the inbreds Pur. 14, Pur. 39, and Pur. 51 were included in the tests each year. As shown in table 3, inbreds Pur. 14, Pur. 51, and Pur. 39 averaged 1, 3, and 6 percent more, respectively, than the predicted number of borers. Data given in table 4 show that this lack of resistance was reflected in the crosses among these three inbreds themselves which averaged 23 percent more than the predicted number of borers.

Attention is directed to the performance of inbred Pur. 14 (table 3) during the period 1935–39, in contrast to its performance during the years 1940–42. Evidently, if the tests of this inbred had been restricted to either period alone, directly opposite conclusions regarding its reaction to the borer would have been derived, that of resistance in the early period of testing and of susceptibility in the later. As discussed above, the predominance of larvae of the single-generation strain of the borer during the early period of testing and of the multiple-generation strain during the later years suggested the possibility of differential reaction of this inbred to the two strains of the borer. Similarly, a number of inbred lines of the Country Gentleman and the Evergreen types have shown diverse reactions to the borer during the two periods described. These are discussed under the two specific types.

Inbred Pur. W675–1 was derived from the open-pollinate sweet corn Kansas Golden by G. M. Smith, of the United States Bureau of Plant Industry, Soils, and Agricultural Engineering, at the Purdue University Agricultural Experiment Station. The seed which he furnished for testing represented a first-year self of a single plant. Two samples of the original lot of seed, one tested in 1938 and the other in 1939, showed 30 and 44 percent less, respectively, than the predicted number of borers. An advanced-generation ear selection from this lot, tested in 1940, showed 17 percent less. The tests were continued in 1941 with seed from two selfed plants of the material tested in 1940. Advance-generation ear selections from one plant showed 67 percent less and from the other, 77 percent less, than the predicted number of borers. The lot of seed showing 77 percent fewer borers was retested

in 1942 and showed 49 percent less than the predicted number of borers. For six tests of Pur. W675–1 during the years 1938–42, this inbred averaged 42 percent less than the predicted number of borers, as compared with 5, 6, and 13 percent more, respectively, for the inbreds Pur. 14, Pur. 51, and Pur. 39, tested during the same period (table 3). Little information is available on the combining ability of inbred Pur. W675–1 in single crosses. Crosses of this inbred with Pur. 14, Pur. 51, and Pur. 39, averaged 14 percent more than the predicted number of borers, as compared with 29 percent more for the three single crosses among Pur. 14, Pur. 51, and Pur. 39, when tested in the same experiment in 1940. The original lot of seed of Pur. W675–1 was represented in the crosses tested.

Inbred Ia. 461 was developed by E. S. Haber, at the Iowa Agricultural Experiment Station. It was derived from the cross Osterland 420 × Ia. 45 and had been inbred for four generations from a backcross to Ia. 45 when furnished by Dr. Haber for testing. The resistance shown by inbred Ia. 461 probably reflected that contributed by inbred Ia. 45. For four successive years of testing (1939–42) inbred Ia. 461 averaged 35 percent less than the predicted number of borers, as compared with 13, 17, and 20 percent more, respectively, for the inbreds Pur. 14, Pur. 51, and Pur. 39, tested during the same years (table 3). The data in table 4 show that the resistance carried by inbred Ia. 461 was reflected in the performance of single crosses containing it. The crosses of inbreds Pur. 14, Pur. 51, and Pur. 39 by inbred Ia. 461 averaged 10 percent less than the predicted number of borers, as compared with 23 percent more for the three crosses among Pur. 14, Pur. 51, and Pur. 39. The crosses of the resistant inbreds Mich. 1828, Ia. 9, and Minn. 26–34 by inbred Ia. 461 averaged 22 percent less than the predicted number of borers, as compared with 13 percent less, 4 percent less, and 10 percent more, for the same inbreds crossed with Pur. 14, Pur. 51, and Pur. 39, respectively.

Inbred Mich. 3116 was developed by C. H. Mahoney at the Michigan Agricultural Experiment Station. Its record of origin was lost at the experiment station, but it was believed to be a derivative of sweet corn crossed by Maize Amargo. Seed of this line was furnished for testing by A. F. Yeager, of the Michigan Agricultural Experiment Station. Inbred Mich. 3116 received 10 tests during the period 1938–42, all of which showed less than the predicted number of borers, the average of the tests being, on a yearly mean basis, 33 percent less (table 3). During the same period inbreds Pur. 14, Pur. 51, and Pur. 39, respectively, averaged 5, 6, and 13 percent more than the predicted number of borers. When tested in 1940, the single crosses of Mich. 3116 by Pur. 14, Pur. 51, and Pur. 39, respectively, showed 10, 18, and 38 percent more than the predicted number of borers in contrast to 23, 25, and 35 percent more for the respective crosses Pur. 14 × Pur. 51, Pur. 39 × Pur. 14, and Pur. 39 × Pur. 51. In the same tests Mich. 3116 × Mich. 1828 showed 31 percent less than the predicted number of borers, as compared with 23 percent less, 2 percent less, and 8 percent more, for Mich. 1828 crossed by Pur. 14, Pur. 51, and Pur. 39, respectively.

Inbred Mich. 1828 was developed by C. H. Mahoney at the Michigan Agricultural Experiment Station. The record of its origin was

lost, but it is believed to be a recovered line from the cross of an early Bantam inbred by Maize Amargo. This inbred received 77 tests, mainly as advanced-generation ear selections, during the 7-year period 1936–42. The tests on a yearly mean basis averaged 33 percent less than the predicted number of borers, in contrast to 1, 3, and 10 percent more, respectively, for the tests of the inbreds Pur. 14, Pur. 51, and Pur. 39 during the same period (table 3). Samples of the original lot of seed of Mich. 1828, furnished by Dr. Mahoney, were tested during the years 1936, 1937, and 1938, and showed 38, 80, and 45 percent less, respectively, than the predicted number of borers. In 1939 a new lot of seed of the inbred produced in an isolation block was received from A. F. Yeager, of the Michigan Agricultural Experiment Station, along with seed of 15 hand-pollinated ears from the same block. This material was tested in 1939 and advanced-generation ear lines, in 1940–42. When tested in 1939 and 1940, samples of the bulked seed of the isolation block showed 21 and 22 percent less, respectively, than the predicted number of borers. Fifteen ear lines tested in 1939 averaged 13 percent less than the predicted number of borers, and 9, 39, and 9 ear lines tested in 1940, 1941, and 1942, respectively, averaged 37, 8, and 9 percent less. In the same experiments in the years 1940–42, 23, 9, and 4 ear lines of Pur. 39, respectively, averaged 10, 39, and 10 percent more than the predicted number of borers.

The contribution of resistance to single crosses by inbred Mich. 1828 has been well established. Five single crosses containing Mich. 1828 averaged 25 percent less than the predicted number of borers when tested in 1937, ranging from 6 to 40 percent less. In the same experiment the cross Pur. 39×Pur. 51 showed 20 percent more than the predicted number of borers. The data in table 4 show that inbreds Pur. 14, Pur. 51, and Pur. 39 crossed by inbred Mich. 1828 averaged 9 percent less than the predicted number of borers, in contrast to 23 percent more for the crosses among themselves. The resistant inbreds Ia. 461, Ia. 9, and Minn. 26–34 crossed by Mich. 1828 averaged 21 percent less than the predicted number of borers, in contrast to 9 and 8 percent less and 9 percent more where the resistant inbreds were crossed by Pur. 14, Pur. 51, and Pur. 39, respectively. In 1940, when Mich. 1828, Pur. 14, Pur. 39, and Pur. 51 were crossed, respectively, with the same 8 inbreds, they averaged 21 percent less, none, 3 percent more, and 14 percent more than the predicted number of borers. In 1941 crosses of Mich. 1828 and Pur. 39, respectively, by the same 37 inbreds, averaged 8 percent less and 12 percent more than the predicted number of borers. In 31 of the 37 comparable pairs of crosses, the cross containing Mich. 1828 showed the lowest level of borer population, and in 6 pairs it showed the highest.

Inbred Ia. S5010–9 was developed by E. W. Lindstrom at the Iowa Agricultural Experiment Station. Six tests of this inbred during the 5-year period 1938–42 averaged 32 percent less than the predicted number of borers, as compared with 5, 6, and 13 percent more, respectively, for the inbreds Pur. 14, Pur. 51, and Pur. 39 (table 3), tested during the same period. Little information was obtained on the performance of Ia. S5010–9 in single crosses. In 1940 a test of Ia. S5010–9×Pur. 51 showed 1 percent less than the predicted number

of borers, as compared with 61 and 9 percent more, respectively, for 2 tests of Pur. 39×Pur. 51, and 23 percent more for one test of Pur. 14×Pur. 51.

Inbred Minn. 13–34 was developed by I. J. Johnson at the Minnesota Agricultural Experiment Station. Three tests of this inbred (table 3) averaged 27 percent less than the predicted number of borers, as compared with 2 and 10 percent less for the inbreds Pur. 39 and Pur. 51 tested during the same period, 1936–38. In 1936 a single test of Minn. 13–34×Golden Bantam showed 18 percent more than the predicted number of borers. No other information was obtained on the performance of inbred Minn. 13–34 in crosses.

Inbred Ia. 9 was developed by E. S. Haber at the Iowa Agricultural Experiment Station. It received 22 tests during the years 1936–42, which on a yearly mean basis averaged 26 percent less than the predicted number of borers, in contrast to 7 and 15 percent more for the inbreds Pur. 51 and Pur. 39, respectively, tested during the same period (table 3). Samples of the original lot of seed tested in 1936, 1937, and 1939, respectively, averaged 47 percent less than the predicted number of borers, as compared with 7 percent less and 11 percent more, respectively, for the inbreds Pur. 51 and Pur. 39 tested during the same years. From 1940 through 1942 the tests of inbred Ia. 9 were continued with advanced-generation ear selections produced at Toledo, Ohio. In 1940 9 ear lines of Ia. 9 averaged 28 percent less than the predicted number of borers, as compared with 1 percent less and 10 and 54 percent more, respectively, for 6, 23, and 8 ear lines of Pur. 14, Pur. 39, and Pur. 51. In 1941 6 ear lines of Ia. 9 averaged 14 percent less and 9 ear lines of Pur. 39 averaged 39 percent more than the predicted number of borers. In 1942 4, 4, 2, and 1 ear lines of Ia. 9, Pur. 39, Pur. 51, and Pur. 14 averaged 18, 10, 18, and 56 percent, respectively, more than the predicted number of borers, on an average. The resistance shown by inbred Ia. 9 was reflected in the performance of single crosses containing it. The data of table 4 show 4 percent less than the predicted number of borers, on an average, for the group of single crosses commonly containing Ia. 9, as compared with 1, 3, and 11 percent more for the respective groups commonly containing Pur. 14, Pur. 51, and Pur. 39. Inbreds Pur. 14, Pur. 51, and Pur. 39, respectively, crossed by inbred Ia. 9 averaged 1 percent more than the predicted number of borers, as compared with 23 percent more for the crosses among themselves.

Inbred Minn. 77 was developed by I. J. Johnson at the Minnesota Agricultural Experiment Station. Four tests of this inbred (table 3) averaged 25 percent less than the predicted number of borers, as compared with 17, 20, and 13 percent more for the inbreds Pur. 14, Pur. 39, and Pur. 51, respectively, tested during the same period, 1939–42. In 1941 the cross Minn. 77×Pur. 39 showed 9 percent less than the predicted number of borers, as compared with 14 percent more for the cross Pur. 39×Pur. 51. In the same experiment the crosses Minn. 77×Mich. 1828 and Pur. 51×Mich. 1828 showed 31 and 24 percent, respectively, less than the predicted number of borers.

Inbred Minn. 26–34 was also developed by I. J. Johnson at the Minnesota Agricultural Experiment Station. From 1936 through 1942 this inbred received 21 tests, which on a yearly mean basis averaged 25 percent less than the predicted number of borers (table 3), as com-

pared with 3 and 10 percent more, respectively, for the inbreds Pur. 51 and Pur. 39 tested during the same period. From 1936 through 1939 the tests involved seed furnished directly by the experiment station. The tests of this material averaged 35 percent less than the predicted number of borers, as compared with 10 percent less and 5 percent more, respectively, for the inbreds Pur. 51 and Pur. 39 tested during the same years. From 1940 through 1942 the tests were continued with advanced-generation ear selections produced at Toledo, Ohio. In 1940, 8 ear lines of Minn. 26–34 averaged 28 percent less than the predicted number of borers, as compared with 10 percent more than predicted for 23 ear lines of Pur. 39. In 1941, 5 and 9 ear lines of Minn. 26–34 and Pur. 39 averaged 12 and 39 percent more, respectively, than the predicted number. In 1942 3 ear lines of Minn. 26–34 averaged 19 percent less, and 4 ear lines of Pur. 39, 10 percent more, than the predicted number. The data of table 4 show the contribution of resistance to single crosses by Minn. 26–34. The group of crosses commonly containing Minn. 26–34 averaged 3 percent less than the predicted number of borers, as compared with 1, 3, and 11 percent more, respectively, than predicted for the groups commonly containing Pur. 14, Pur. 51, and Pur. 39. Inbreds Pur. 14, Pur. 51, and Pur. 39 crossed by inbred Minn. 26–34 averaged 1 percent more than the predicted number of borers, as compared with 23 percent more for the crosses among themselves.

Inbred Wis. 515 was developed by N. P. Neal at the Wisconsin Agricultural Experiment Station. In 1939, 1940, and 1942 single tests of this inbred averaged 22 percent less than the predicted number of borers (table 3), as compared with 14, 18, and 18 percent more, for the inbreds Pur. 39, Pur. 14, and Pur. 51, respectively, tested during the same years. Little information was obtained on the performance of Wis. 515 in single crosses. In 1941 the respective crosses Wis. 515 × Mich. 1828 and Pur. 51 × Mich. 1828 showed 4 percent more and 24 percent less than the predicted number of borers. In the same experiment the crosses Wis. 515 × Pur. 39 and Pur. 39 × Pur. 51, showed 65 and 14 percent more, respectively, than the predicted number of borers. In both comparisons the crosses containing Wis. 515 showed inferior performance in resistance.

Inbred Ia. 45 was developed by E. S. Haber at the Iowa Agricultural Experiment Station. It is one of the component inbred parents of the commercial hybrid Ioana, IP39 × Ia. 45. Inbred Ia. 45 averaged 15 percent less than the predicted number of borers on a yearly mean basis for 8 years of testing, 1935–42. The tests were made with seed obtained directly from the experiment station during the years 1935–39. These tests averaged 26 percent less than the predicted number of borers, as compared with 7 and 1 percent less, respectively, for the inbreds Pur. 51 and Pur. 39 tested during the same years (table 3). The tests were continued with seed produced at Toledo, Ohio, during the period 1940–42. These later tests of Ia. 45 averaged 4 percent more than the predicted number of borers per plant as compared with 18, 20, and 26 percent more, respectively, for the inbreds Pur. 39, Pur. 51, and Pur. 14. The results obtained with inbred Ia. 45 during the period 1940–42 may have reflected differential behavior of the line under multiple-generation borer infestation, as previously discussed. Fourteen different crosses of Ia. 45 were given 23 tests through 1936–42, and averaged 10 percent fewer borers

than the number predicted. In contrast, through 1935–42, 15 different crosses of Pur. 14 given 34 tests, 22 different crosses of Pur. 51 given 65 tests, and 54 different crosses of Pur. 39 given 114 tests, averaged 6, 13, and 14 percent more borers, respectively, than the number predicted. The commercial cross Ia. IP39 × Ia. 45 (Ioana), tested through 1940–42, showed 24, 5, and 8 percent fewer borers than the number predicted, respectively, as compared with 35 (average of 2 tests), 12 (average of 3 tests), and 19 percent more borers, respectively, for the commercial cross Pur. 39 × Pur. 51, (Golden Cross Bantam) tested through the same period. Tested in 1937 and 1940–41, the cross Pur. 51 × Ia. 45 showed 3, 46, and 3 percent more borers, respectively, than the number predicted. Tested in 1937 and 1940, the cross Pur. 39 × Ia. 45 showed 7 percent less and 8 percent more borers, respectively, than the predicted number.

BORER RESISTANCE OF COUNTRY GENTLEMAN INBRED LINES

The following Country Gentleman inbreds were classed as resistant to the survival of corn borer larvae; Ill. 8, Ia. 1445, Ia. 1627, Ia. 1434, Pur. FR34, Pur. S36, Pur. 6691, Pur. 7620, Pur. 8035, and Wis. 360. The first three lines listed were in commercial production and the remainder were experimental. The data obtained for the lines, in comparison with data for the susceptible inbred Pur. 6355, are given in table 5. Data also are given in table 5 for the inbreds Pur. S10 and Pur. FR22, although their classification is uncertain. Both Pur. S10 and Pur. FR22 consistently showed less than the predicted number of borers when tested during the period 1937–39 and consistently more in tests during the years 1940–42. Similar differentiations in the results of the early and later tests were shown by a number of other lines (table 5). An explanation for the shift might be found as described earlier, in the strain of borer used, because the early tests mainly involved larvae of the single-generation strain, whereas larvae of the multiple-generation strain predominated during the period 1940–42, and the corn lines may have reacted differently to the two borer strains.

The results of most tests of crosses involving the inbred lines given in table 5 are presented in tables 6 and 7. The data in table 6 show

TABLE 5.—*Relative resistance of inbred lines of Country Gentleman sweet corn to European corn borer larvae, Toledo, Ohio, 1935–41, and Lafayette, Ind., 1942*

Inbred line [1]	Total number of tests	Tests showing less than predicted number of borers	Percent deviation of observed from predicted borer population [2]								
			1935	1936	1937	1938	1939	1940	1941	1942	Mean
Ia. 1627	4	4	------	------	------	------	------	−58	−28	−41	−42
Ia. 1434	3	3	------	−62	−8	−42	------	------	------	------	−37
Ia. 1445	14	13	−35	−45	−3	−5	−6	+2	−36	−34	−20
Wis. 360	5	4	------	------	------	------	−3	−28	−11	−24	−17
Pur. 6691	6	5	------	------	−9	−18	−15	+7	−5	−51	−15
Pur. S36	7	5	------	------	−9	−28	−16	−47	+25	−3	−13
Ill. 8	27	15	−36	−10	−18	+10	+4	+22	−1	−27	−7
Pur. 8035	6	4	------	------	−25	−28	−14	−8	+30	+4	−7
Pur. FR34	5	3	------	−22	------	+12	------	+19	−27	−16	−7
Pur. 7620	6	4	------	------	−21	−22	−1	−32	+46	+20	−2
Pur. S10	6	3	------	------	−4	−35	−10	+27	+42	+42	+10
Pur. FR22	6	3	------	------	−29	−18	−30	+22	+94	+74	+19
Pur. 6355	5	0	------	+74	+25	------	+10	------	+53	+3	+33

[1] Breeders: Iowa, E. S. Haber; Wisconsin, N. P. Neal; Illinois, W. A. Huelsen; Purdue, G. M. Smith.
[2] Where more than a single test was involved in a single year the mean result is given

the results obtained in 1940 for crosses of the inbreds by the same four lines, with a few exceptions, and that of table 7 the results for all possible single crosses among the inbreds themselves when tested in 1941. While the results obtained in 1940 generally were not in agreement with those shown for 1941, the data for both years were pooled as a larger sample to evaluate the relative combining abilities of the inbred lines. On this basis, the average deviations from the predicted number of borers were −5, −1, +5, +6, +7, +8, +10, and +15 percent for the groups of crosses involving Ill. 8, Ia. 1445, Pur. 8035, Pur. S36, Pur. FR22, Pur. S10, Pur. 7620, and Pur. 6355, respectively. Because of the preponderance of resistant inbreds in the pedigrees of the crosses, these results express the differences among the groups on an average basis, rather than in percentages of resistance or susceptibility according to some standard. It is significant, however, that the group of crosses involving the susceptible inbred Pur. 6355 had the highest average population shown (table 7). The lack of conformity of the data of table 6 in this regard has no explanation, unless it may be in the material used in the small number of crosses involved.

The behavior in single crosses of the Country Gentleman inbreds Pur. FR34, Pur. 6691, Ia. 1434, and Ia. 1627 (table 5) is discussed below. No crosses of inbred Wis. 360 were tested during the period reported herein. Data for crosses involving the inbreds Pur. FR34

TABLE 6.—*Percentage deviation of observed from predicted population of European corn borer larvae in single crosses among Country Gentleman inbred lines of sweet corn, Toledo, Ohio, 1940*

Inbred line	Inbreds used in crosses				
	Ill. 44a	Ill. 24a	Pur. FR34	Ill. 49a	Mean
Pur. 6691	−56	+6	−23	+8	−16
Pur. FR22	−20	+31	−46	−7	−11
Pur. 8035	−3	−32	+20	+6	−2
Ill. 8	−52	−15	−19	+125	+10
Pur. S36	+10	−12	+39	+9	+12
Pur. 7620	+29	+5	+21		+18
Ia. 1445	+2	−23	+43	+60	+21
Pur. S10	−17		−2	+84	+22
Pur. 6355	+25		−19	+7	+4

TABLE 7.—*Percentage deviation of observed from predicted population of European corn borer larvae in single crosses of Country Gentleman inbred lines of sweet corn, Toledo, Ohio, 1941*

Inbred line	Inbreds used in crosses							
	Ia. 1445	Ill. 8	Pur. S10	Pur. S36	Pur. 7620	Pur. 8035	Pur. FR22	Pur. 6355
Ia. 1445		−31	+4	−24	−3	−2	−46	+5
Ill. 8	−31		+4	−17	−25	+2	−17	−9
Pur. S10	+4	+4		−43	−14	+5	+19	+43
Pur. S36	−24	−17	−43		−15	+32	+82	+5
Pur. 7620	−3	−25	−14	−15		+9	+55	+44
Pur. 8035	−2	+2	+5	+32	+8		+3	+17
Pur. FR22	−46	−17	+19	+82	+55	+3		+23
Pur. 6355	+5	−9	+43	+5	+44	+18	+24	
Mean	−14	−13	+3	+3	+7	+10	+17	+18

and Pur. 6691 are shown in table 6. The comparable crosses involving Pur. 6691 and Pur. 6355, respectively, averaged 24 percent less and 4 percent more than the predicted number of borers. When crossed by the same 7 inbreds, Pur. FR34 (table 6) and Pur. 6355 (table 7) averaged 8 and 19 percent more, respectively, than the predicted number of borers. These comparisons, however, should be viewed with caution for the reasons given previously. Of 11 tests of Ia. 1434 crosses involving 9 inbred lines during 1936 and 1937, 7 showed less and 4 showed more than the predicted number of borers, averaging 5 percent less. When tested in 1940, 1941, and 1942, repectively, the cross Ia. 1627×Ia. 1445 (in commercial production as Iogent 27) showed 40, 37, and 44 percent fewer borers than the predicted number, this being the only cross tested involving inbred Ia. 1627.

BORER RESISTANCE OF EVERGREEN INBRED LINES

The data obtained on borer resistance for the more promising Evergreen inbreds are given in table 8, with data on the susceptible inbred Pur. 8448 for comparison. The inbreds were Ill. 11, 13, and 55; Ia. 1071, 1248, S5017–1, S5316–5, S5328–1; Md. H33, H84, and H126; Ohio 27e; Pur. 119, 1009, 1014, 1099, 1101, 1103, and 1105; and Wis. 637. Among them, the inbreds Ill. 11, Ill. 13, Ill. 55, and Md. H84 currently are in commercial production. As was noted in a number of the Country Gentleman inbreds (table 5), the data of table 8 show that a number of the Evergreen lines behaved differently when tested in the years preceding 1940 and in the years after 1939. This is especially notable for the inbreds Pur. 119 and Pur. 1099. As

TABLE 8.—*Relative resistance of inbred lines of Evergreen sweet corn to European corn borer larvae, Toledo, Ohio, 1935–41, and Lafayette, Ind., 1942*

Inbred line	Breeder	Total number of tests	Tests showing less than predicted number of borers	Percent deviation of observed from predicted borer population								
				1935	1936	1937	1938	1939	1940	1941	1942	Mean
Ia. S5316–5	E. W. Lindstrom.	3	3	.....	.....	.....	.....	−26	−25	−75	.....	−42
Ia. S5328–1	do	4	4	.....	.....	.....	.....	0	−59	−49	.....	−36
Ia. S5017–1	do	5	5	.....	.....	.....	.....	−25	−30	−44	−29	−32
Ia. 1071	E. S. Haber	7	6	−9	−56	+5	−24	.....	−6	−60	−45	−28
Wis. 637	N. P. Neal	4	3	.....	.....	.....	.....	−33	−24	−53	+13	−24
Md. H126	G. M. Rothgeb.	15	10	.....	+10	.....	+82	−22	+8	−45	−2	−22
Ohio 27e	J. B. Park	3	3	.....	−30	−15	−20	.....	.....	.....	.....	−22
Md. H33	G. M. Rothgeb.	6	4	.....	.....	−27	−36	−18	+11	+27	−58	−17
Pur. 1014	G. M. Smith	5	4	.....	−16	−18	−36	+4	.....	.....	.....	−17
Ia. 1248	E. S. Haber	3	3	.....	−24	−12	−21	.....	.....	.....	.....	−16
Md. H84	G. M. Rothgeb.	4	4	.....	.....	−34	−15	.....	.....	−1	−13	−16
Pur. 1103	G. M. Smith	5	4	.....	.....	.....	−21	−18	−27	+31	−12	−9
Pur. 1101	do	7	5	.....	−28	+8	−26	−21	+21	−4	−12	−9
Ill. 55	W. A. Huelsen	13	8	.....	.....	.....	−10	−2	+13	−34	.....	−8
Ill. 13	do	23	13	.....	−30	−6	−20	−7	−4	+16	+2	−7
Pur. 1009	G. M. Smith	11	7	−7	−47	+10	−15	−7	+20	−42	+37	−6
Ill. 11	W. A. Huelsen	13	6	.....	−40	+11	.....	+14	+2	−17	−5	−6
Pur. 1105	G. M. Smith	6	4	.....	.....	.....	+11	−16	+19	−20	.....	−4
Pur. 119	do	7	4	.....	−6	−19	−20	−27	+32	+14	+10	−2
Pur. 1099	do	6	3	.....	+20	+23	.....	+50	−16	−34	−14	+5
Pur. 8448	do	4	0	.....	.....	.....	+6	+23	.....	+24	+20	+18

discussed previously, the differences shown during the respective periods of testing may be a reflection of the differential reaction of the inbreds to the larvae of the single- and the multiple-generation strains of the borer. The former was predominant during the early years of testing and the latter during the later years.

Data for the results obtained in 1940 and 1941 are shown in tables 9 and 10, respectively, for single crosses involving groups of the Evergreen inbred lines listed in table 8. The data in table 9 show comparisons among the inbreds Pur. 1009, Pur. 119, Pur. 1105, Md. H33, Pur. 1014, Md. H126, Pur. 1103, and Pur. 8448 when these lines were crossed by the inbreds Pur. 1099, Ill. 11, Ill. 13, and Pur. 1101, respectively (column of mean results at right), and also comparisons among the latter inbreds when crossed by the former (line of results at bottom). The data in table 10 show comparisons among the inbreds Pur. 119, Ia. 1071, Md. H126, Ill. 13, Pur. 1101, Pur. 8448, and Md. H33 when these lines were crossed among themselves in all possible single-cross combinations. With the exception of Pur. 8448, the inbred components of the crosses tested represented resistant lines, therefore the range from negative to positive deviations from the predicted borer populations expressed the relative degrees of difference among the crosses, rather than their degrees of resistance or susceptibility relative to a standard. The lowest larval populations were shown in 1940 (table 9) on an average basis, by the groups of crosses involving the inbreds Pur. 1009, Pur. 119, and Pur. 1099, respectively, and in 1941 (table 10) by the groups of crosses involving the inbreds Pur. 119 and Ia. 1071, respectively. In 1941, with the exception of the crosses involving inbred Md. H33, the highest average borer population was shown for the group commonly containing the susceptible inbred Pur. 8448. In 1940, on the basis of comparable crosses, the crosses involving inbreds Pur. 1009, Pur. 119, and Pur. 1105 showed lower levels of larval pupulations, on an average, and the crosses involving the inbreds Md. H33, Pur. 1014, Md. H126, and Pur. 1103, showed higher borer populations than the crosses involving the susceptible inbred Pur. 8448.

Of the remainder of the inbred lines listed in table 8 and not discussed above, the following were not tested in crosses during the period reported herein: Ia. S5017–1, Ia. 5316–5, Ia. 5328–1, Ohio 27e, and Wis. 637. A single test of inbred Ill. 55 crossed by Ill. 11 in 1941 showed 39 percent less than the predicted number of borers. Four

TABLE 9.—*Percentage deviation of observed from predicted population of European corn borer larvae in single crosses of Evergreen inbred lines of sweet corn, Toledo, Ohio, 1940*

Inbred line	Inbreds used in crosses				
	Pur. 1099	Ill. 11	Ill. 13	Pur. 1101	Mean
Pur. 1009	+8	−6	−33	−23	−14
Pur. 119	−17	−28	+27	+4	−4
Pur. 1105	−14	+2	+29	−8	+2
Md. H33	−4	−9	+16	+39	+11
Pur. 1014	+10	+26	+20	+3	+15
Md. H126	−10	−11	+40	+65	+21
Pur. 1103	−13	+23	−14	+121	+29
Pur. 8448	−35	+41	----------	−6	0
Mean [1]	−6	0	+12	+29	+9

[1] Exclusive of Pur. 8448 crosses.

TABLE 10.—*Percentage deviation of observed from predicted population of European corn borer larvae in single crosses of Evergreen inbred lines of sweet corn, Toledo, Ohio, 1941*

Inbred line	Inbreds used in crosses						
	Pur. 119	Ia. 1071	Md. H126	Ill. 13	Pur. 1101	Pur. 8448	Md. H33
Pur. 119	------	−59	+3	+9	+14	−16	−43
Ia. 1071	−59	------	−4	−17	−34	+39	+11
Md. H126	+3	−4	------	−17	+49	−30	+1
Ill. 13	+9	−17	−17	------	−6	+35	+53
Pur. 1101	+14	−34	+49	−6	------	+8	+46
Pur. 8448	−16	+39	−30	+35	+8	------	+79
Md. H33	−43	+11	+1	+53	+46	+79	------
Mean	−15	−11	0	+10	+13	+19	+25

crosses involving inbred Md. H84 averaged 14 percent less than the predicted number of borers, 3 showing less and 1 showing more. The remaining inbred Ia. 1248, not discussed above, received 11 tests in crosses involving 8 inbred lines and averaged 12 percent less than the predicted number of borers, 5 of the crosses showing less and 3 showing more.

SUMMARY

Tests were conducted at Toledo, Ohio, during the period 1935–41, and at Lafayette, Ind., in 1942 to determine the inbred lines of sweet corn resistant to larvae of the European corn borer (*Pyrausta nubilalis* (Hbn.)). Materials for this investigation were furnished by Federal and State agencies and consisted of experimental and released sweet corn lines of domestic origin. In addition to natural infestation, the entries were uniformly infested by hand with corn borer egg masses and the plants were dissected for borer counts when the larvae were approximately full grown. The effects on the borer counts of known variable conditions of test were corrected by multiple-regression methods, and the results are expressed in terms of the percentage deviations of the observed from the predicted numbers of borers, which afforded the basis for evaluating the test entries.

Of 977 sweet corn inbreds examined for inherent resistance to the larvae of the European corn borer, none showed immunity, but 44 did manifest some resistance, having from 42 to 2 percent fewer borers than were predicted for them after tests extending over a period of 3 or more years. The results obtained from single crosses indicated incomplete dominance of either resistance or susceptibility. The intercrosses of resistant and susceptible parents generally showed results intermediate between those obtained for crosses within resistant and susceptible groups of inbreds. Although relatively low in inherent resistance, the discovered materials constitute resistant stocks of possibly differing factors for breeding strains of greater resistance. High resistance is probably due to the cumulative effects of several factors.

Among the lines tested the following are in commercial use: Bantam type—Pur. 39, Pur. 51, Pur. 14, Minn. 77, and Ia. 45; Country Gentleman type—Ia. 1627, Ia. 1445, Ill. 8, and Pur. FR22; and Evergreen type—Md. H84, Ill. 55, Ill. 13, and Ill. 11.

The Bantam type inbreds found resistant were Pur. W675–1, Ia. 461, Mich. 3116, Mich. 1828, Ia. S5010–9, Minn. 13–34, Ia. 9, Minn.

77, Minn. 26–34, Wis. 515, and Ia. 45. These ranged in resistance from 42 to 15 percent less than the predicted number of borers for the conditions of test, as compared with 3 and 6 percent more than predicted for the susceptible inbreds Pur. 51 and Pur. 39, respectively.

The Country Gentleman type inbreds found resistant were Ia. 1627, Ia. 1434, Ia. 1445, Wis. 360, Pur. 6691, Pur. S36, Ill. 8, Pur. 8035, Pur. FR34, and Pur. 7620. These ranged in resistance from 42 to 2 percent less than the predicted number of borers for the conditions of test, as compared with 33 percent more for the susceptible inbred Pur. 6355.

The Evergreen type inbreds found resistant were Ia. S5316–5, Ia. S5328–1, Ia. S5017–1, Ia. 1071, Wis. 637, Md. H126, Ohio 27e, Md. H33, Pur. 1014, Ia. 1248, Md. H84, Pur. 1103, Pur. 1101, Ill. 55, Ill. 13, Pur. 1009, Ill. 11, and Pur. 1105. These ranged in resistance from 42 to 4 percent less than the predicted number of borers for the conditions of test, as compared with 18 percent more than predicted for the susceptible inbred Pur. 8448.

The Bantam type inbred Pur. 14, the Country Gentleman type inbreds Pur. S10, and Pur. FR22, and the Evergreen type inbred Pur. 119, showed apparent resistance when tested during the period 1935–39, when the single generation of the borer predominated, but showed apparent susceptibility when tested during the period 1940–42, when the multiple-generation strain of the borer predominated. An opposite trend was shown by the Evergreen type inbred Pur. 1099 for the two test periods. In the absence of critical research a premise of differential reaction of the same lines of sweet corn to infestation by the different strains of the borer must be viewed with caution.

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A BASIS FOR CLASSIFYING SOIL PERMEABILITIES[1]

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INTRODUCTION

Appraisals of soil permeability are based generally on readily observed soil characteristics, such as texture, structure, and compaction, but the relation of these qualitative appraisals to actual rates of water movement through soils has not been fixed with any degree of certainty or uniformity. Quantitative data are needed to develop fixed standards for permeability classes, in view of the importance that is attached to this soil property in adapting conservation practices to land use and management. Unfortunately, measurements of the permeability of soils in place are difficult to make, and are impractical for extensive classifications.

Measurements have been made on samples of soil, removed from their natural position but otherwise undisturbed, to determine permeabilities. These determinations have been based frequently on some method of pore-space analysis (*3*), (*4*). (*6*).[3]

The removal of soil samples or cores from their natural location may alter somewhat the normal field permeability characteristics of the individual sample. Possible smearing of surfaces or compaction during sampling may reduce the subsequently measured permeability relative to the normal field permeability in place. Also, the mere operation of cutting the core may open fortuitous channels throughout the core that would normally be blocked had the core been left in place, and so cause an increase in the measured permeability over the normal field permeability. Otherwise, provided the samples are handled in a manner to simulate field conditions as nearly as possible, the measured rates should approximate the field rates of the segments sampled.

The natural interrelation of the permeabilities of the various soil layers in place is lost in any sampling procedure. Permeability ratings based on core samples can be stated as applying only to that layer of soil from which the sample is taken. Over-all profile permeability or capacity for water intake must be estimated from consideration of the permeability and position of the individual soil layers that make up the soil profile.

The permeabilities on which this paper is based are those determined

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[3] Italic numbers in parentheses refer to Literature Cited, p. 168.

by measurements of segments of soil profiles. The assumption is made that these indirect permeability measurements approximate the normal permeabilities of the samples in place under natural conditions. On this basis, soils that were grouped in descriptive permeability classes have been examined, and the classes have been defined in rate terms.

METHODS

The method of measuring permeability used in this study is based on a procedure suggested by Bendixen and Slater (*1*). They have shown that the introduction of a time factor into pore space-drainage measurements made under tension results in an integrated weighting of the effect of pore sizes on permeability. The amount of pore space drained in short-time intervals is considered to be an improved measure of relative permeabilities.

For the practical application of the procedure to this study the amount of pore space drained in 1 hour under 60 cm. of water tension was taken as an index of relative permeability. All pore space-drainage measurements were made at this time interval. It appeared from the original study (*1*) that any time interval from 10 minutes to 2 hours could be made to serve equally well.

Percolation rates were determined in order to get an estimate of permeability in rate terms. Although these determinations also were made on tension plates, the rates are reported as comparable to rates measured under the conditions of unit head.[4]

Core samples were obtained in brass cylinders, 3 inches in diameter and 3 inches in height, by means of an Ohio type sampler, which is designed to take samples with a minimum disturbance of their natural structure. Mechanically, the sampler is an improvement of the type described by Yoder (*7*). Five replicates were taken at each soil depth.

On removal from the sampler, each core was trimmed flush with the ends of the containing cylinder. Cores were transported in pint ice-cream cartons.

At the laboratory a piece of cotton cloth was stretched over the bottom of the core and held in place with a rubber band. Brass rings 1 inch high and of the same diameter as the cylinders were then placed on top of the core and sealed in place with melted paraffin. These provided capacity for a ¼-inch head of water that was later put on the cores. The cores were then weighed and placed in large pans of water for saturation. A piece of window screen was first laid in the bottom of the pan to insure free water movement under the cores. For the first few hours the cores were kept in shallow water which was gradually deepened until the level of the water was just at the top of the cylinders. The cores were allowed to saturate about 18 hours.

[4] It was determined experimentally that the percolation rates of cores on the tension plate responded to tension increases up to about 20 cm. of tension under the conditions of the experiment. At that point tension at the plate ruptured capillary contacts (*5*) and further attempts to increase tension reduced the rate of percolation. At 60 cm. of tension the percolation rates were not increased greatly over normal gravitational flow. Corrections to unit head were not made in view of the large sampling error that is involved in the determination of percolation rates on core samples.

On removal of the cores from the saturation pans, 50 mm. of water was added to supply the free waterhead, and the cores were immediately transferred to a Leamer and Shaw tension plate (*2*), set at 60 cm. of tension, for percolation.

The time at which each core was placed on the tension plate was noted. The head of water was maintained on the cores by adding measured amounts of water as necessary. Percolation was continued for a 4-hour period. At the end of 4 hours the cores were removed from the plate and the excess water poured off and measured. The time when each core was removed was noted and the total time of percolation was determined. From the total amount of water added, less that amount remaining when the core was removed from the plate, the amount of water passing through the core was obtained. The percolation rate in inches per hour was then calculated.

After the percolation test, the cores were weighed immediately to get the saturated weight and were then replaced on the tension plate. They were allowed to drain under tension for 1 hour, were removed, and weighed again. The difference between the drained weight and the saturated weight was found. A correction of this figure was made to account for the water held by and drained from the cloth over the bottom of the core. The amount of pore space drained was calculated as a percentage of core volume.

DATA AND DISCUSSION

COASTAL PLAINS SOILS

The general relationship between the amount of pore space drained in 1 hour under 60 cm. of tension and the percolation rates for a group of Coastal Plains soils is shown in figure 1. Data on 310 individual cores from various depths in 7 soils were obtained, but, to avoid crowding in reproduction, only a portion of these are plotted. The soils represent permeabilities that range from very rapidly to slowly permeable as characterized by field observations.

A very definite correlation between the amount of pore space drained and the respective percolation rates is apparent and is indicated by a line. Deviations from the line are less, relatively, for the pore-space measurements. The lesser variance of the pore-space measurements was shown to be statistically significant in a previous paper (*1*), where it was also shown that the variation between soils was greater for the pore-space measurements than for the percolation measurements. The pore-space measurements thus seemed to furnish the more desirable index of permeability, a point that is further confirmed by the present data. However, since permeabilities are usually stated quantitatively as rates of flow, it is necessary to have some measure of percolation rates in order to interpret pore-space measurements in rate terms. The regression of percolation rates on pore space as indicated in figure 1 may be used to determine the relationship of these factors for the local Coastal Plains soils, but before attempting to apply the relationship to soils generally the variations that might occur in the relationship should be discussed.

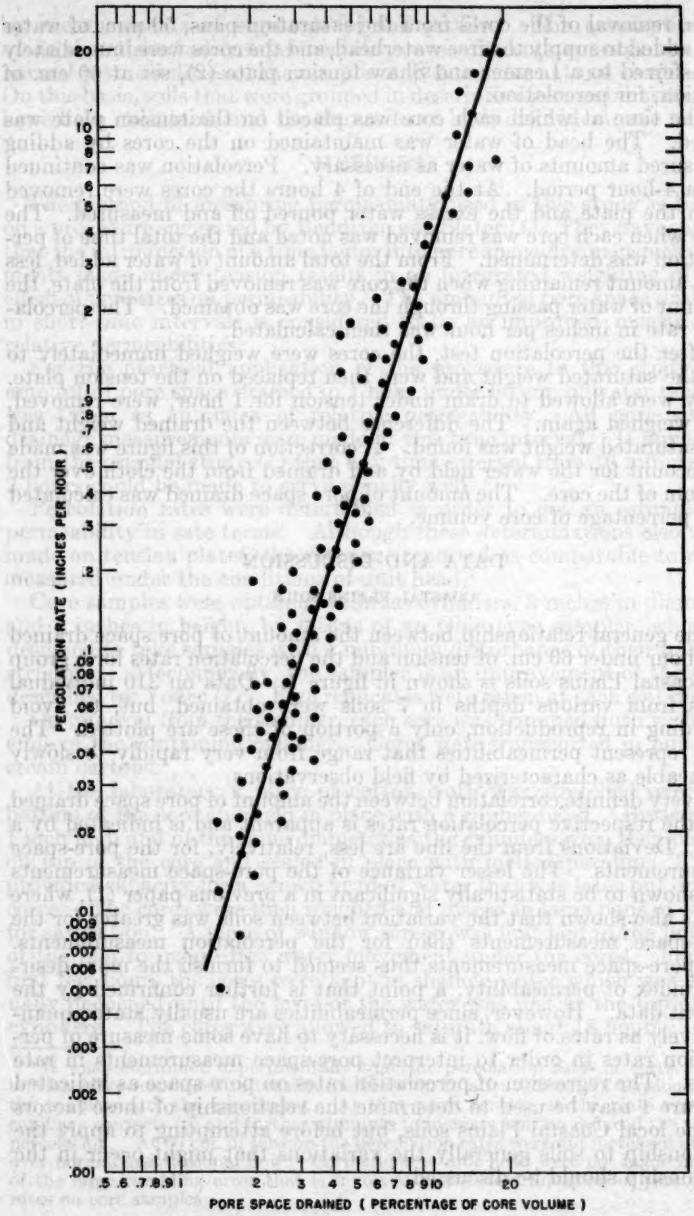

FIGURE 1.—Relation of percolation rates to amount of pore space drained for a group of Coastal Plains soils.

OHIO SOILS AND THE EFFECT OF STRUCTURE

Textural differences do not affect greatly the general regression of permeability on pore space. This becomes evident when it is known that the Coastal Plains soils in figure 1 cover a textural range from loamy sands to heavy clays. Differences in structure among the Coastal Plains soils likewise did not affect seriously the general relationship. However, it is to be expected that the relationship might vary with greater differences in structural characteristics, dependent on the degree to which structure affects pore-size distribution and continuity. Thus when two differently structured soils are saturated and then drained under tension for a fixed time interval, equal volumes of pores may be drained, but at different rates of drainage, and so represent different classes of pore sizes.

The pores that drain in a well-structured heavy-textured soil may do so almost immediately when tension is applied, and there may be but little further drainage. Pores in a less structured, lighter textured soil may drain at a slower rate but continue to drain over a longer time interval. The pores that drain at the faster rate are the larger pores that are associated with high percolation rates. Consequently, a well-structured heavy-textured soil may be expected to have a faster percolation rate than a relatively less-structured soil for equal amounts of pore space drained.

The variation in the percolation-pore space relationship that is associated with structure is illustrated in figure 2. Lines are drawn that represent this relationship for 11 different soil profiles. They tend to fall into 2 groups. Four soil profiles from northwestern Ohio, representing the Brookston and Paulding series, constitute group A. Local Coastal Plains soils constitute group B, which includes profiles of the Matawan, Muirkirk, Sunnyside, Hyattsville, Beltsville, Leonardtown, and Christiana series. In comparison with the Ohio group, these are all relatively weak-structured soils. Percolation rates for the Ohio group are higher than the rates for the Coastal Plains group, for the amount of pore space drained.

As previously noted, the Coastal Plains group includes a wide range of textures. In figure 2 the failure of textural differences to disperse the lines of group B may be noted. The separation of group A from group B coincides with structural differences between the groups.

The differences exhibited by the two groups of soils in figure 2 indicate that the use of pore-space measurements to determine percolation rates or relative permeabilities must be limited to soils that have a common pore space-percolation rate relationship. In the section that follows, the local Coastal Plains soils have been considered to be such a group.

RELATION OF PORE-SPACE AND PERCOLATION MEASUREMENTS TO DESCRIPTIVE CLASSES OF SOIL PERMEABILITY

Until recently five permeability classes were used in field descriptions of Maryland soils. Soils were designated as very rapidly, rapidly, moderately, slowly, or very slowly permeable on a profile basis. To express the permeability of a soil completely, however, it is necessary to state it in terms of the separate permeabilities of each of the significantly different layers of the soil profile. The profiles of the Coastal

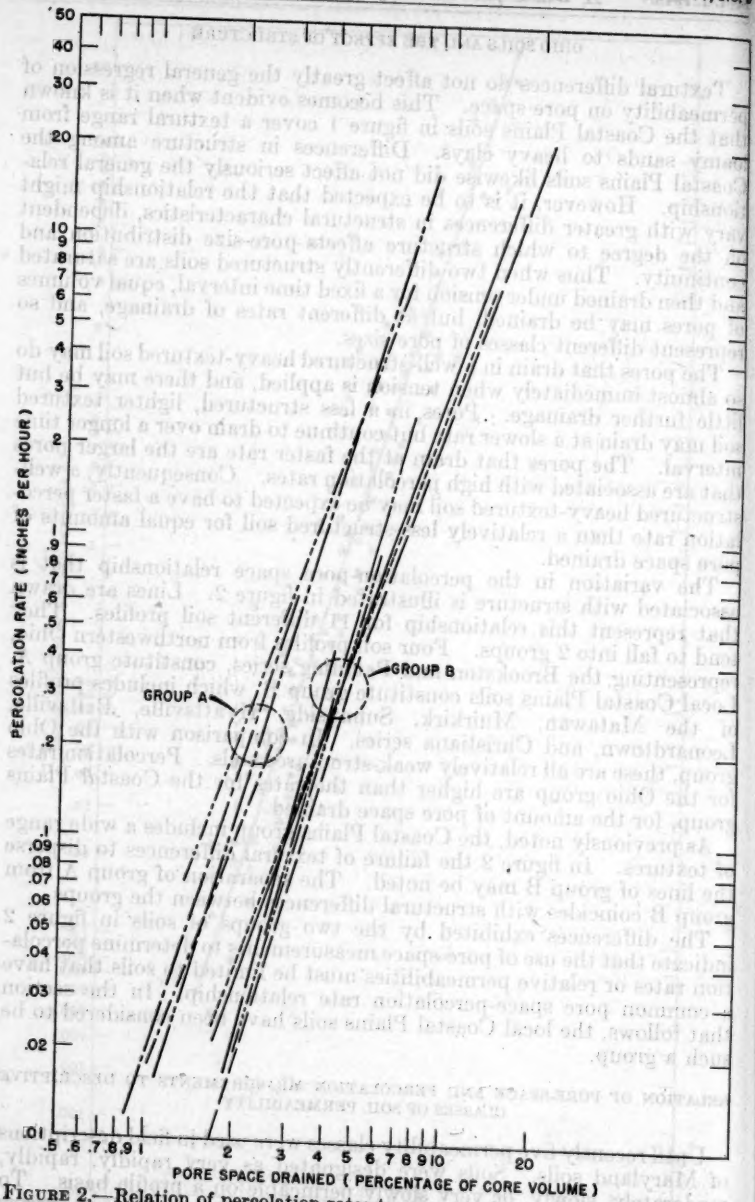

FIGURE 2.—Relation of percolation rates to amount of pore space drained in two groups of soils of widely different structural characteristics: Group A, four soil profiles from northwestern Ohio, representing the Brookston and Paulding series; group B, seven profiles of local Coastal Plains soils.

Plains soils used in these studies have been described in this way, based on a consensus of field judgments. It is on this basis that core samples have been assigned to permeability classes. The permeability class and the amount of pore space drained is given in table 1 for each depth of soil that was sampled.

It will be noted that the descriptive classes are closely related to the amount of pore space drained. Moderately permeable layers are found in five of the seven profiles that were sampled. The Muirkirk loamy sand is moderately permeable in the 16- to 19-inch layer. The Hyattsville loam is moderately permeable at all sampled depths above 30 inches. The Beltsville and Christiana silt loams are moderately permeable in the 3- to 6-inch layer only. A moderately permeable layer is found in the Sunnyside sandy loam at a depth of 9 to 12 inches. The amount of pore space drained in any of these moderately permeable layers lies within the limits of 4.11 to 7.63 in percentage of core volume.

Other classes of permeability are similarly related to the amount of pore space drained. The rapidly permeable class corresponds to a drained-pore-space range of from 8.28 to 13.20 percent. The slowly permeable class corresponds to a drained-pore-space range of from 1.77 to 3.08 percent. Obviously, the very rapidly and very slowly permeable classes lie above and below these limits.

The pore-space ranges found to coincide with the classifications have been assembled in table 2. As might have been expected from an examination of but seven soils, the complete range of pore-space percentages has not been covered by the limits that were found to agree with the classes of permeability. Some adjustment of the limits is necessary to cover the range, and further adjustment is allowable because of the inaccuracies both in pore-space measurements and in the assignment of the various soil layers to permeability classes.

Minor adjustment of the pore-space ranges that define the permeability classes makes it possible to state permeabilities in whole numbered values of drained pore space. The adjusted values are given in the third column of table 2.

Pore-space measurements are used to fix the limits of the permeability classes in order to avoid some of the difficulties that are inherent in percolation measurements. For general use, however, expressions of permeability as rates of transmission in inches per hour are more acceptable. The values for drained pore space can be translated into rate terms from the general pore-space-percolation relationship shown in figure 1. As taken directly from figure 1, the rate limits in inches per hour terminate in odd values, as did the values for drained pore space. The odd values, rounded off to one significant digit, are given in the fourth column of table 2. They define in rate terms the five classes of permeability that were used to group soils in this study.

TABLE 1.—*Amount of pore space drained and permeability classification at given depths for 7 Coastal Plains soils*

Soil	Depth of soil sampled											
	3 to 6 inches		9 to 12 inches		16 to 19 inches		21 to 24 inches		27 to 30 inches		34 to 37 inches	
	Permeability class	Pore space drained [1]	Permeability class	Pore space drained [1]	Permeability class	Pore space drained [1]	Permeability class	Pore space drained [1]	Permeability class	Pore space drained [1]	Permeability class	Pore space drained [1]
		Percent		*Percent*		*Percent*		*Percent*		*Percent*		*Percent*
Muirkirk	Very rapid	17.46	Rapid	8.28	Moderate	7.63						
Matawan							Rapid	13.20	Rapid	8.86	Slow	2.14
Sunnyside	Rapid	12.02	Moderate	4.48	Slow	2.88	Slow	2.20	Slow	2.14		
Hyattsville	Moderate	5.78	do	5.28	Moderate	5.72	Moderate	5.22	Moderate	4.62	Slow	3.06
Beltsville	do	4.86	Slow	3.08	Slow	2.94	Slow	2.14	Slow	3.06		
Christiana	do	4.11	do	2.20	do	1.77	do	2.26	do	2.34		
Leonardtown	Slow	3.28	do	2.92	do	2.06	do	3.08				

[1] In percentage of core volume.

TABLE 2.—*Permeability classifications as related to amount of pore space drained in 1 hour at 60 cm. of tension and comparable percolation rates*

Permeability classification	Amount of pore space drained [1]		Percolation rate, per hour, adjusted
	Actual	Adjusted	
	Percent	*Percent*	*Inches*
Very rapid		More than 14	More than 8.
Rapid	8. 28–13. 20	8–14	2–8.
Moderate	4. 11–7. 63	4–8	0. 2–2.
Slow	1. 77–3. 08	1.5–4	0. 01–0. 2.
Very slow		Less than 1.5	Less than 0.01.

[1] In percentage of core volume.

MISSOURI SOILS

Pore-space measurements on a group of Missouri soils were obtained from E. S. Vanatta [5] and R. E. Uhland,[5] and were used as a base in classifying these soils into permeability groups. This was done to test further the relationship between amount of pore space drained and permeability classifications. It was felt that the relative permeabilities should follow the pore-space measurements, provided the soils of the group were not widely divergent in their structural characteristics.

Permeabilities as measured by percolation rates would coincide with the rate table that has been set up only if the Missouri soils were similar with respect to the effect of their structural characteristics on permeability to the soils on which the table is based. Percolation data are not available on these Missouri soils, and only a single expression of permeability was used in the field description to characterize each soil profile.

The original pore-space data on these soils were based on a 2-hour drainage interval and have been reduced by 10 percent [6] to approximate the 1-hour drainage data on which the rest of the paper is based. The data are tabulated in table 3.

The data show that the amount of pore space drained in all layers of the Pettis silt loam, from 7.1 to 10 percent, fall within or near the rapidly permeable range as defined in table 2. The over-all field classification of permeability is also given as rapidly permeable.

Every depth in the Putnam silt loam but one had less than 1.5 percent of core volume drained, that is, each layer is in the very slowly permeable class. The over-all field classification for the profile is also very slowly permeable.

Four of the five soils classed in the field as moderately permeable show amounts of pore space drained at all depths that are close to the defining values for the moderately permeable class.

[5] With the U. S. Department of Agriculture, Soil Conservation Service.

[6] On the basis of data where both the 1-hour and 2-hour drainage values are available on about 500 cores, the average amount of pore space drained in 1 hour was 10 percent less than that drained in 2 hours.

TABLE 3.—*Amount of pore space drained* [1] *at given depths and permeability classification for 12 Missouri soils*

Soil	Permeability classification	Pore space drained at a depth of—				
		3 to 6 inches	6 to 9 inches	12 to 15 inches	18 to 21 inches	24 to 27 inches
		Percent	*Percent*	*Percent*	*Percent*	*Percent*
Pettis	Rapid	7.1	9.5	10.3	9.1	10.0
Lindley	Moderate	7.4	7.1	7.0	5.2	3.7
Surprising	do	6.8	9.0	8.0	6.2	3.1
Shelby	do	3.2	9.1	7.1	4.6	3.9
Do	do	7.9	9.9	10.3	12.1	3.2
Shelby, eroded	do	8.3	12.1	3.5	2.5	
Grundy	Slow	10.3	8.4	11.8	8.7	2.6
Summit	do	9.2	12.4	10.8	3.1	4.0
Mexico	do	7.1	6.9	5.3	3.9	3.5
Weller	do	5.2	6.2	4.7	3.2	3.2
Edina	Very slow	8.8	5.4	8.1	4.1	3.8
Putnam	do	1.0	1.0	1.6	.7	1.4

[1] In percentage of core volume.

The fifth soil, classed in the field as moderately permeable, is an eroded Shelby silt loam. It would be more correctly classified, according to the amount of pore space drained, as rapidly permeable to about 12 inches, underlain by slowly permeable layers.

The Summit, Weller, and Mexico profiles, all classed in the field as slowly permeable, have slowly permeable layers below 18 inches, overlain by more permeable layers, according to the amount of pore space drained. The Grundy silt loam, also classed in the field as slowly permeable, appeared to be slowly permeable below 24 inches and more permeable above that depth.

On the basis of pore-space measurements, it appears that the Edina profile, which has been classed in the field as very slowly permeable, could fall equally well in the slowly permeable group. However, it has a lower percentage of drained pore space in the 6- to 9-inch layer than any member of the slowly permeable group. It is probable that this circumstance is reflected in the field behavior of this soil and accounts for its lower classification in the field rating.

It is evident from the comparisons that have been made that the pore-space classification of permeabilities, based on local Coastal Plains soils, is also in practical agreement with the field classifications of the Missouri soils. From a practical point of view it appears probable that a fixed relationship between pore space and permeability can be assumed for a great majority of soils. Structural differences must be marked in order to affect appreciably the general pore space-percolation relationship.

PRESENT STATUS OF SOIL PERMEABILITY CLASSIFICATION

The five classes of permeability given in table 2 were considered in making field estimates of permeability of the Coastal Plains soils. In more recent work toward setting up soil-mapping units significant in planning conservation on farms, need has been indicated for seven classes. The seven classes proposed for field estimates of permeability, and their correlation with the five classes used in this study, are given in table 4.

TABLE 4.—*Comparison of the rate limits of the 5-group classification of permeability used in this study with the rate limits of a proposed 7-group classification*

Class No.	Permeability class	Permeability rate per hour	Class No.	Permeability class	Permeability rate per hour
		Inches			*Inches*
1	Very slow	Less than 0.01.	1	Very slow	Less than 0.05.
2	Slow	0.01–0.2.	2	Slow	0.05–0.2.
3	Moderate	0.2–2.0.	3	Moderately slow	0.2–0.8.
4	Rapid	2.0–8.0.	4	Moderate	0.8–2.5.
5	Very rapid	8.0 or more.	5	Moderately rapid	2.5–5.0.
			6	Rapid	5.0–10.0.
			7	Very rapid	10.0 or more.

The limits of the permeability classes are, of course, tentative. As more data are obtained it may be possible to define the limits more closely with respect to field judgment, particularly as tests are made and are correlated with field judgments in widely separated areas. Ultimately, a degree of standardization should ensue, so that soil layers anywhere classed, for example, as moderately permeable, will have a percolation rate within known limits.

SUMMARY

A need for definitions of the descriptive classes of soil permeability, in terms of rate of water movement, is recognized. A combination of measurements of amount of pore space drained in 1 hour under 60 cm. of water tension and of percolation rates was used as a basis for developing such definitions.

Data on a group of local Coastal Plains soils were given that show the general relationship between amount of pore space drained and percolation rates. A definite correlation is apparent. The data on these soils show that the general relationship is reasonably constant for soils of widely different textural composition.

Data on a group of Ohio soils were given to show how the relationship may change for soils of widely different structural characteristics, because of the effect structure has on pore-size distribution and continuity.

Definitions of permeability classes in rate terms have been developed. The limits of the permeability classes were first defined in terms of the amount of pore space drained. Then, from the general pore space-percolation relationship, the comparable permeability rates were obtained. This procedure was adopted because pore-space measurements appeared to be the more reliable measure of permeability.

A partial test was made of the quantitative definitions of permeability on a group of Missouri soils. The pore-space classification of permeability based on Coastal Plains soils was found to be in practical agreement with the field classification of the Missouri soils.

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